Purdue University

Integrating Research into Today's Wind Industry

WIndiana 2010
Indianapolis, IN

Energy Center at Discovery Park
July 22, 2010

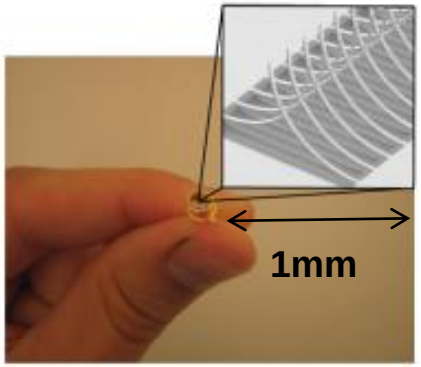
PURDUE UNIVERSITY

WIndiana 2010

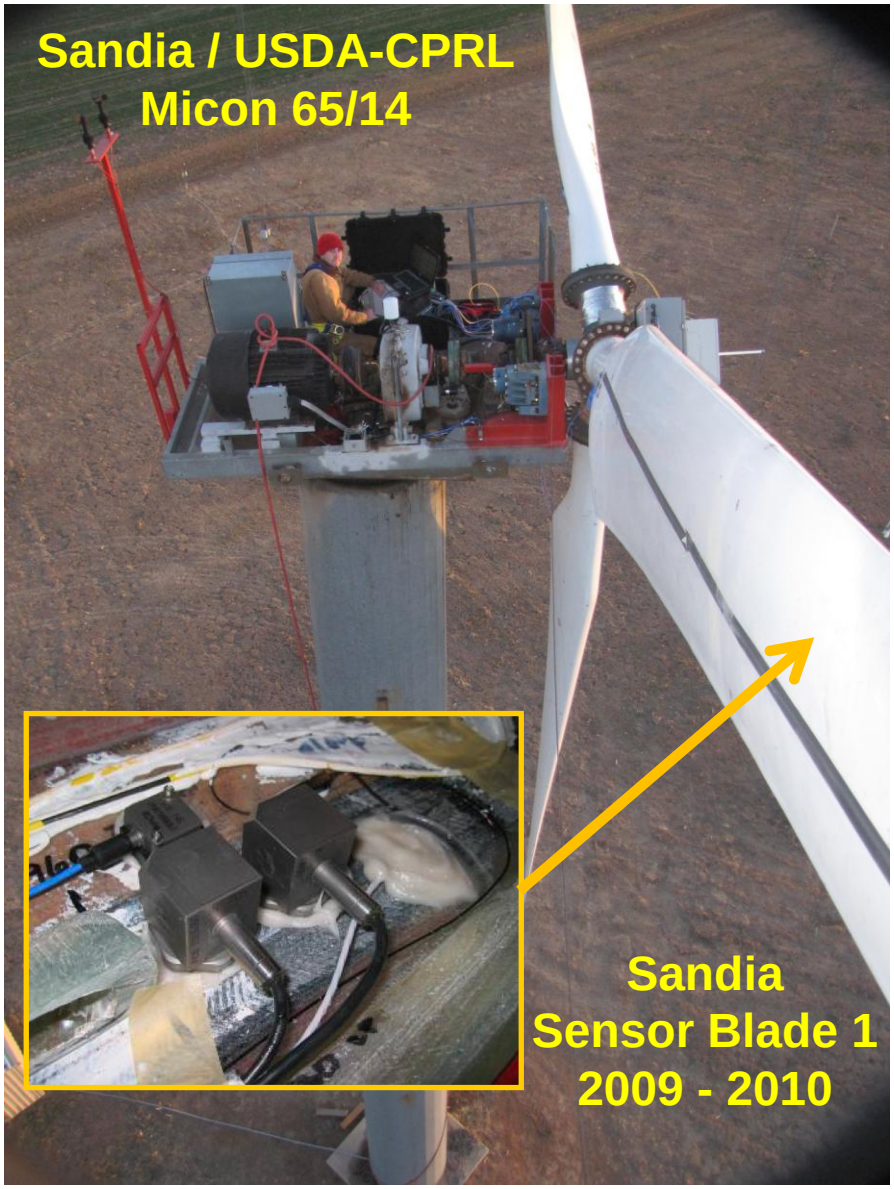
Our Research Vision

Smart Wind Turbines & Farms

that can sense, predict, and control their own performance & reliability

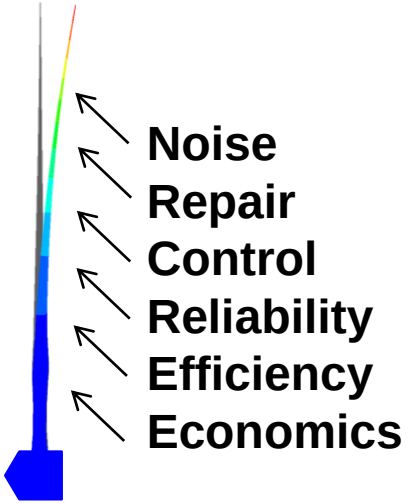


MEMS bimorph temperature sensor



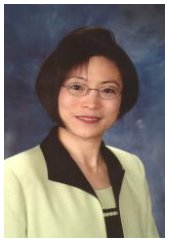
Simulation Based Models

that can help engineers and owners optimize wind turbines and wind farms



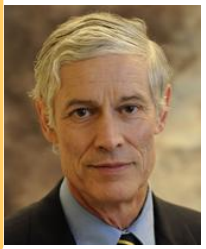
Our People

Rotors/fluid-structure


Economics/policy





Reliability/ maintenance

Sensing


Dynamics & control



Power electronics



Noise

Climatology

Composite materials



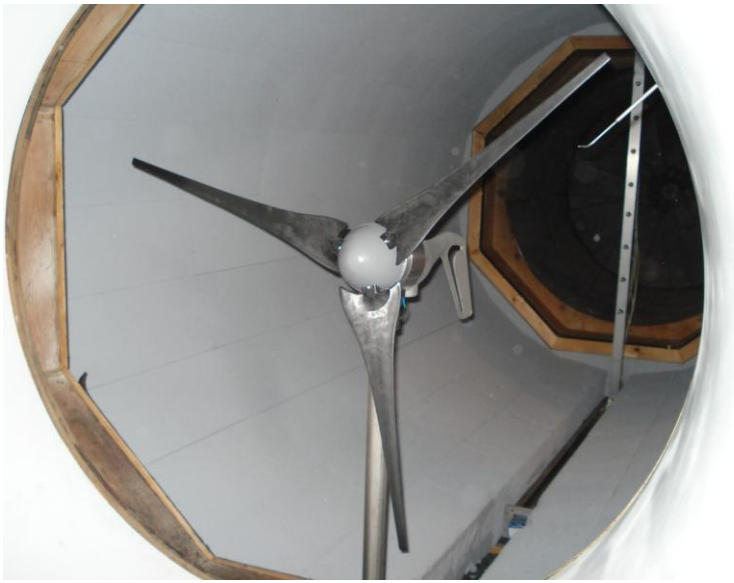
Alternative drive trains

INDIANA UNIVERSITY BLOOMINGTON

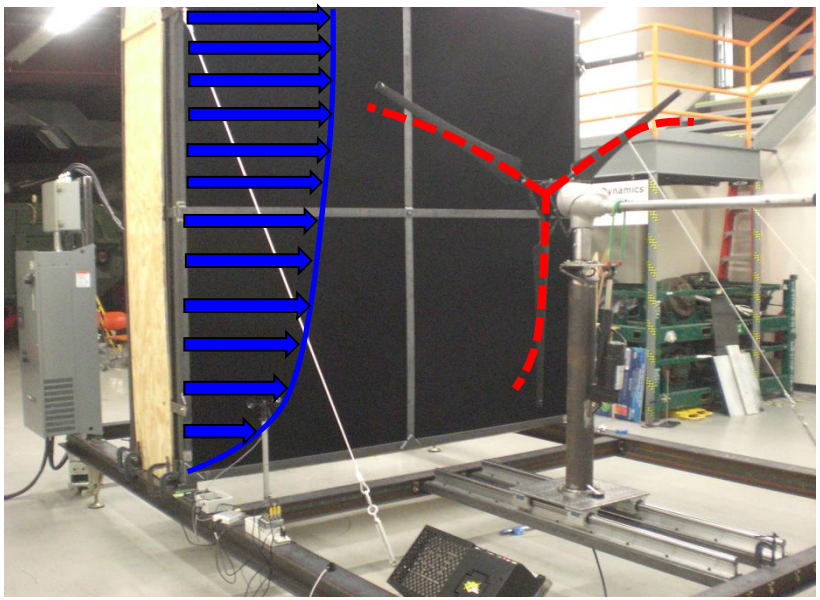
UNIVERSITY OF NOTRE DAME

TAYLOR UNIVERSITY
www.taylor.edu

Research Facilities



Anechoic Wind Tunnel

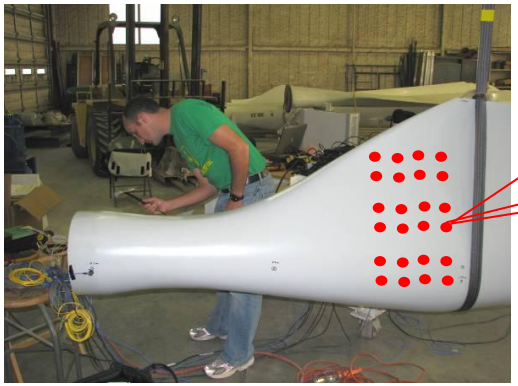


HAWT Dynamics & Controls Testbed

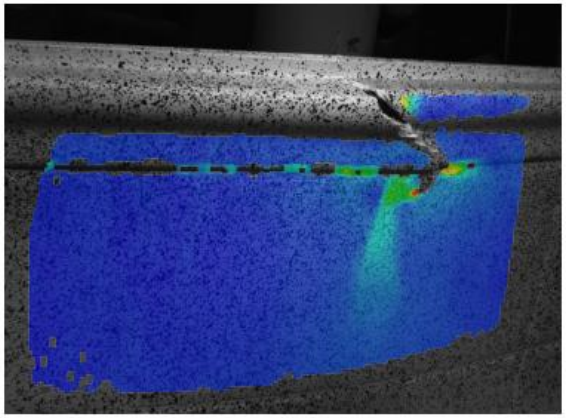
Reconfigurable Micro Wind Farm (see poster in Exposition)

Research Facilities

Turbine blade test facility
(under development)



Polytec 3D Laser Velocimetry System

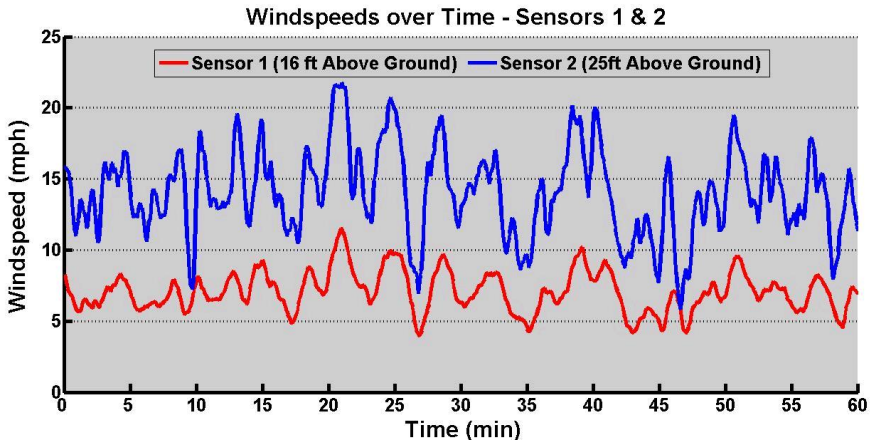


Trillion ARAMIS 3D
Digital Image Correlation System

Numerous rotating machinery
test rigs

Engineering Challenges

Enercon E-126
Germany 2008
6 MW - 127 m diameter
131 m tower



1. Mega-structures
2. Varying wind loads
3. Energy systems

Coal plants
Hydro plants
Nuclear plants

Reliability & Maintenance (2¢/kWh)

Photo credit © Scott Degraw/National Geographic Television

Lifecycle costs

Equipment costs are usually only 5-10% of the lifecycle cost (service and maintenance costs)

(1) Quality control

Durability testing and factory and field inspections to ensure quality.

(2) Maintenance on demand

Unscheduled maintenance is 500% more costly than scheduled service.

(3) Autonomic logistics and control

Order parts ahead of time to maximize uptime while continuing to produce power with advanced controls.

Reliability & Maintenance (2¢/kWh)

Photo credit © Scott Degraw/National Geographic Television

Lifecycle costs

Equipment costs are usually only 5-10% of the lifecycle cost (service and maintenance costs)

(1) Quality control

Durability testing and factory and field inspections to ensure quality.

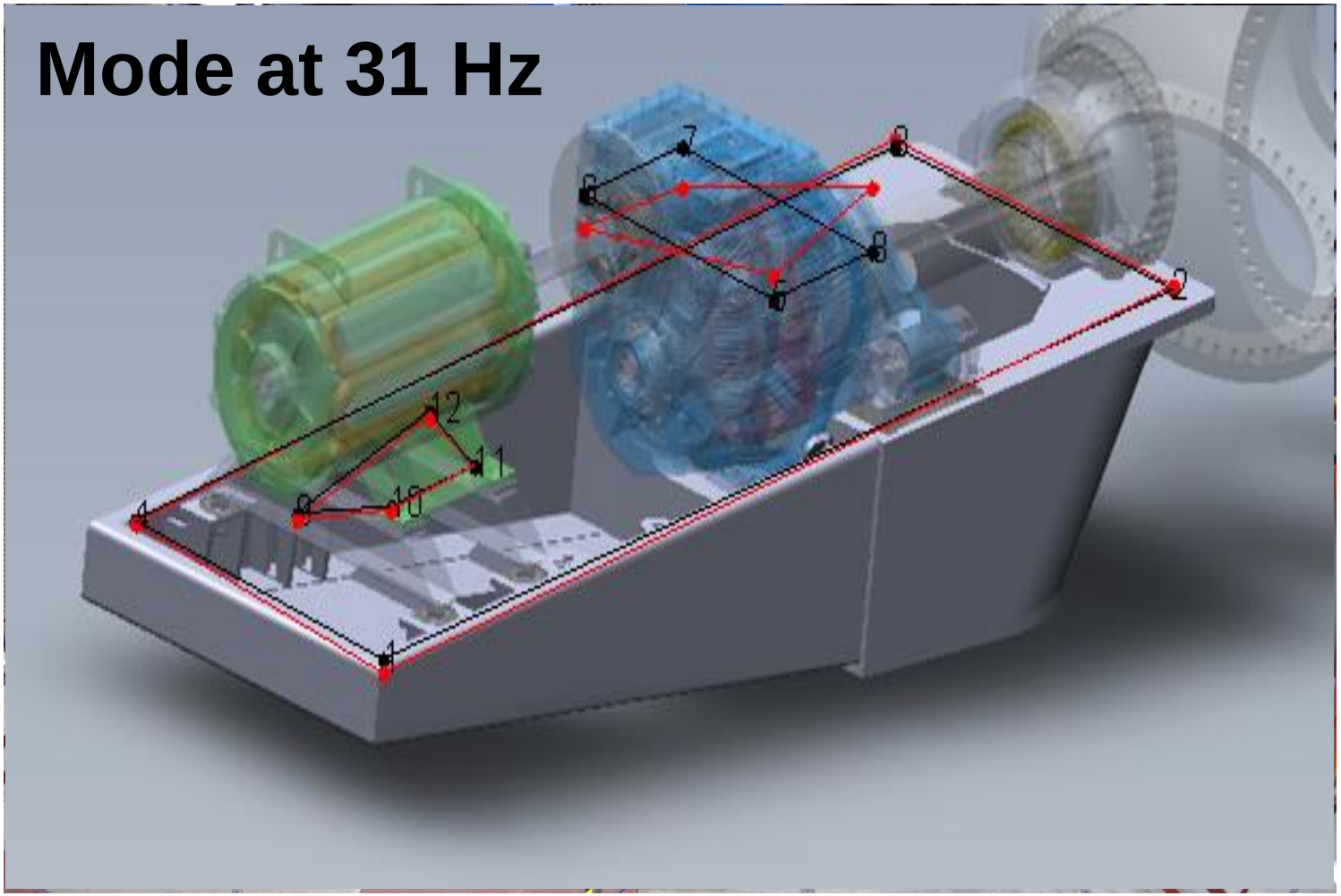
(2) Maintenance on demand

Unscheduled maintenance is 500% more costly than scheduled service.

(3) Autonomic logistics and control

Order parts ahead of time to maximize uptime while continuing to produce power with advanced controls.

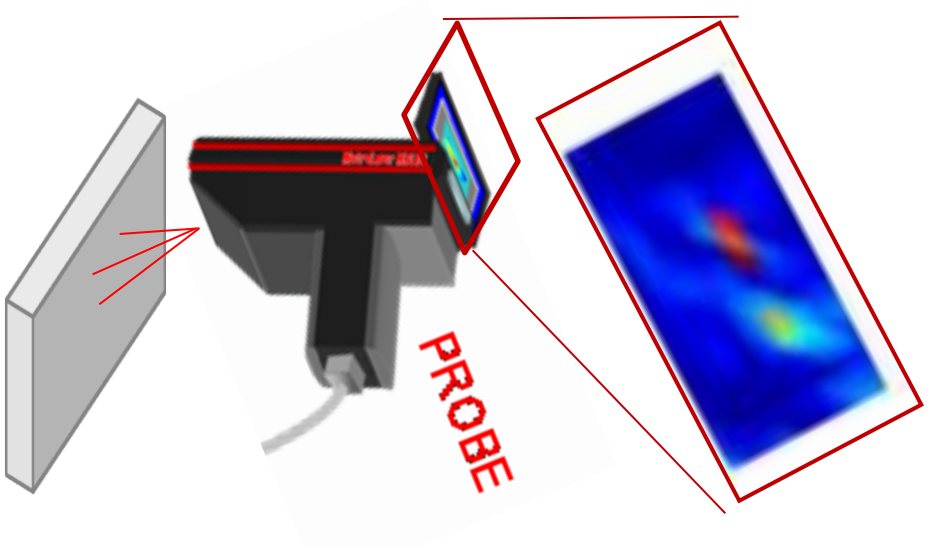
Drivetrain Dynamics (Durability Testing)



750 kW gearbox drivetrain tested at NREL Wind Technology Center

Blade Inspection (Quality Assurance)

SBIR Phase II



Courtesy Dr. V. Markov (Metrolaser, Inc.)

Reliability & Maintenance (2¢/kWh)

Photo credit © Scott Degraw/National Geographic Television

Lifecycle costs

Equipment costs are usually only 5-10% of the lifecycle cost (service and maintenance costs)

(1) Quality control

Durability testing and factory and field inspections to ensure quality.

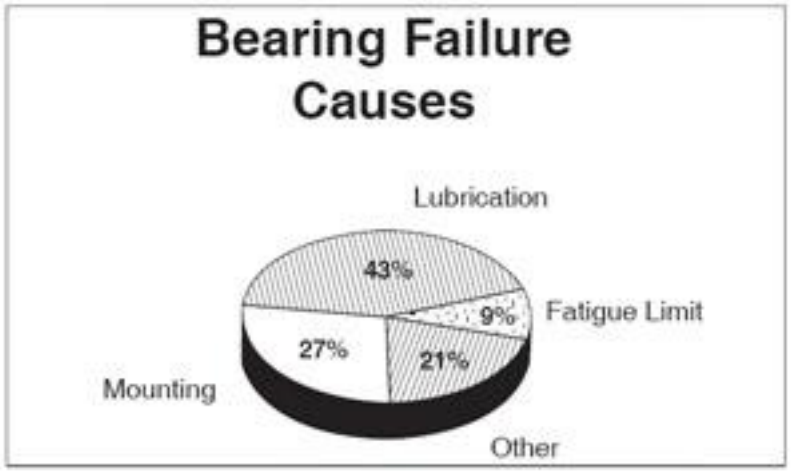
(2) Maintenance on demand

Unscheduled maintenance is 500% more costly than scheduled service.

(3) Autonomic logistics and control

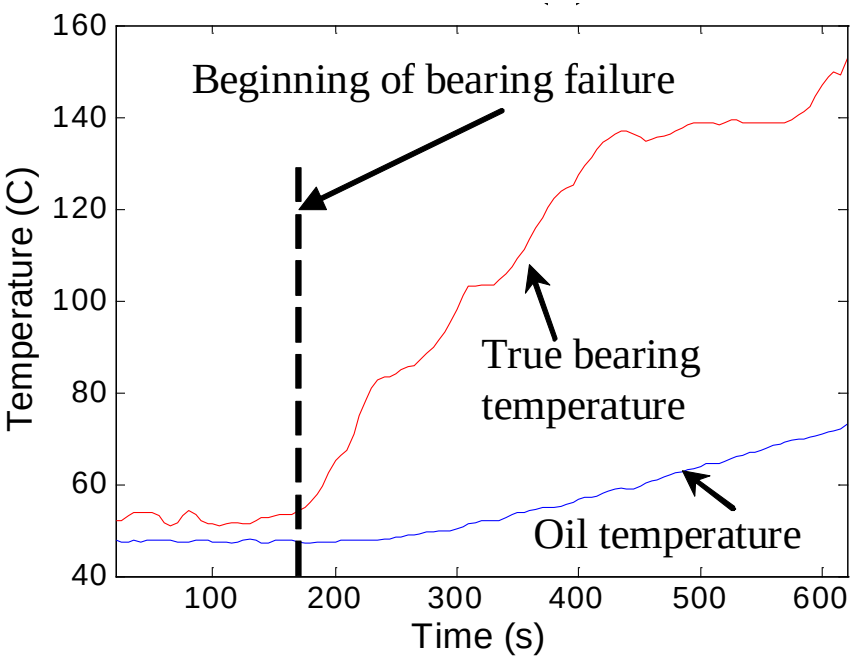
Order parts ahead of time to maximize uptime while continuing to produce power with advanced controls.

Diagnostic Sensing (Maintenance)

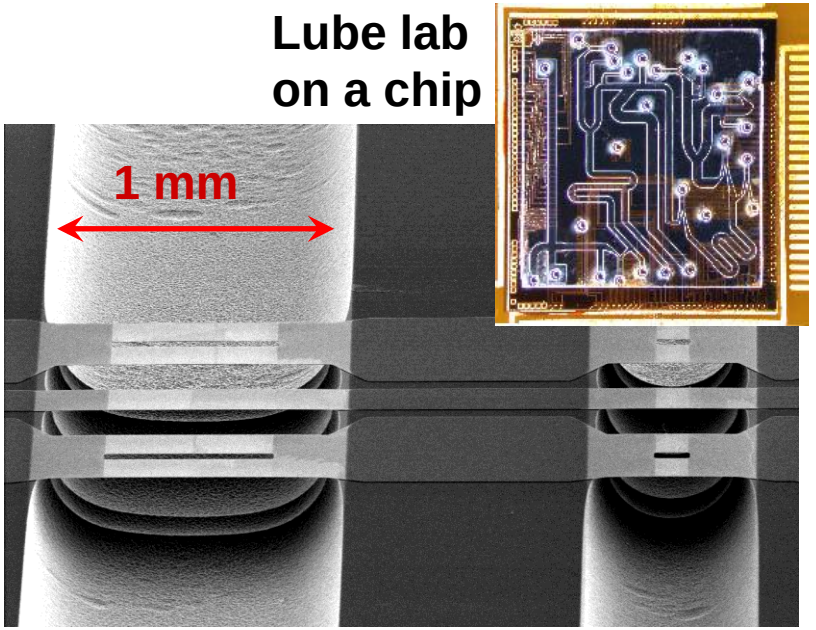


Courtesy powertransmissions.com

MEMS temperature telemeter (Sadeghi)



Lube lab on a chip



Peroulis et al., 2001

Reliability & Maintenance (2¢/kWh)

Photo credit © Scott Degraw/National Geographic Television

Lifecycle costs

Equipment costs are usually only 5-10% of the lifecycle cost (service and maintenance costs)

(1) Quality control

Durability testing and factory and field inspections to ensure quality.

(2) Maintenance on demand

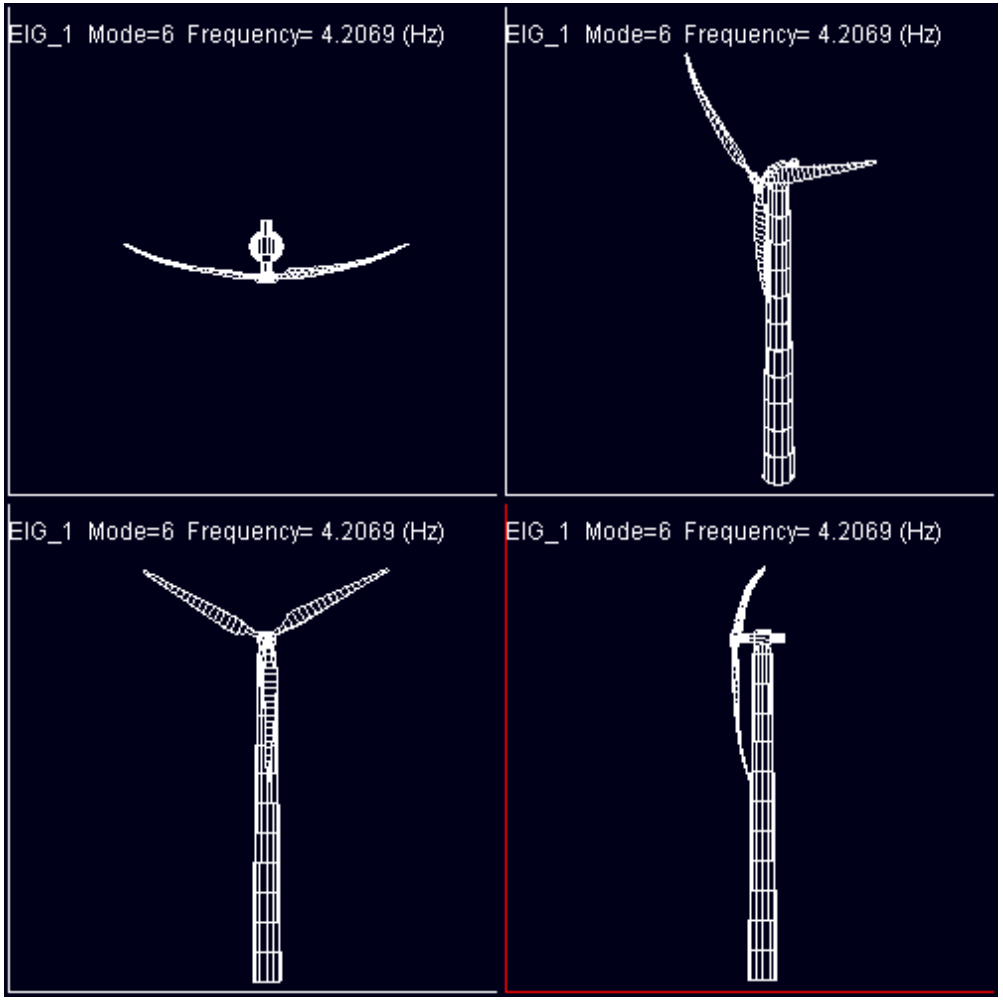
Unscheduled maintenance is 500% more costly than scheduled service.

(3) Autonomic logistics and control

Order parts ahead of time to maximize uptime while continuing to produce power with advanced controls.

Turbine Dynamics (Control)

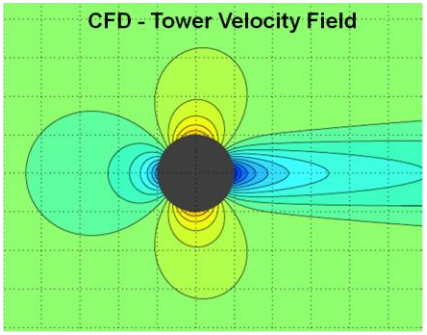
Turbine modeling (all modes within 8%)

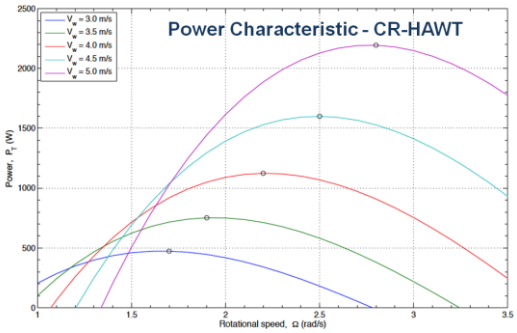


Rotor monitoring (Sorian Inc., partner)

Aerodynamics (Performance)

- Wind Resource - Purdue ASREC Facility
  - 50-m met tower data being analyzed
- Tower-Rotor Interaction Analysis (Fleeter)
  - Discrete Tones, Power, Fatigue
- Wind Farm Performance Optimization
  - Wind Farm - Atmospheric Boundary Layer Interaction Modeling
  - Purdue Micro-Wind Farm
    - Turbine-Turbine Interactions & Control
- Small - Urban Wind Turbines
  - Actuator Disk Theory
    - Single Rotor – $C_{p\text{-}max}$ = 59.3% (Betz limit)
    - Dual Rotor (VAWT) - $C_{p\text{-}max}$ = 64.0%
    - Counter-Rotating Wind Turbine - $C_{p\text{-}max}$ = 84%
  - VAWT - WL & Calumet

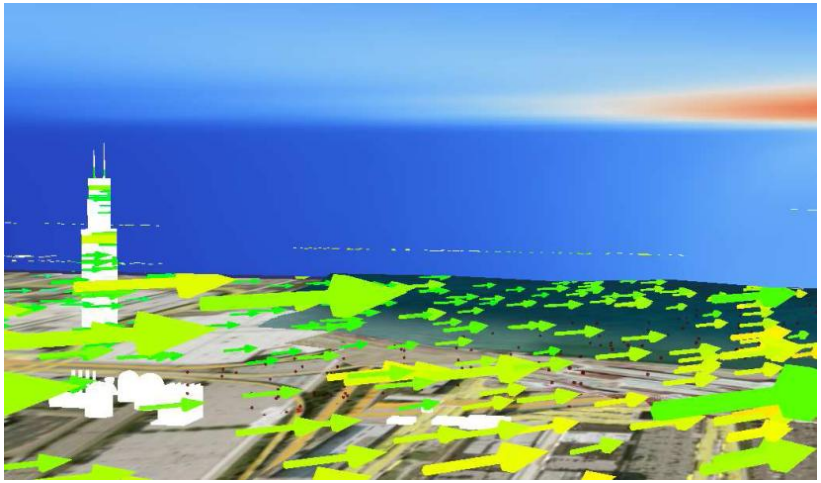




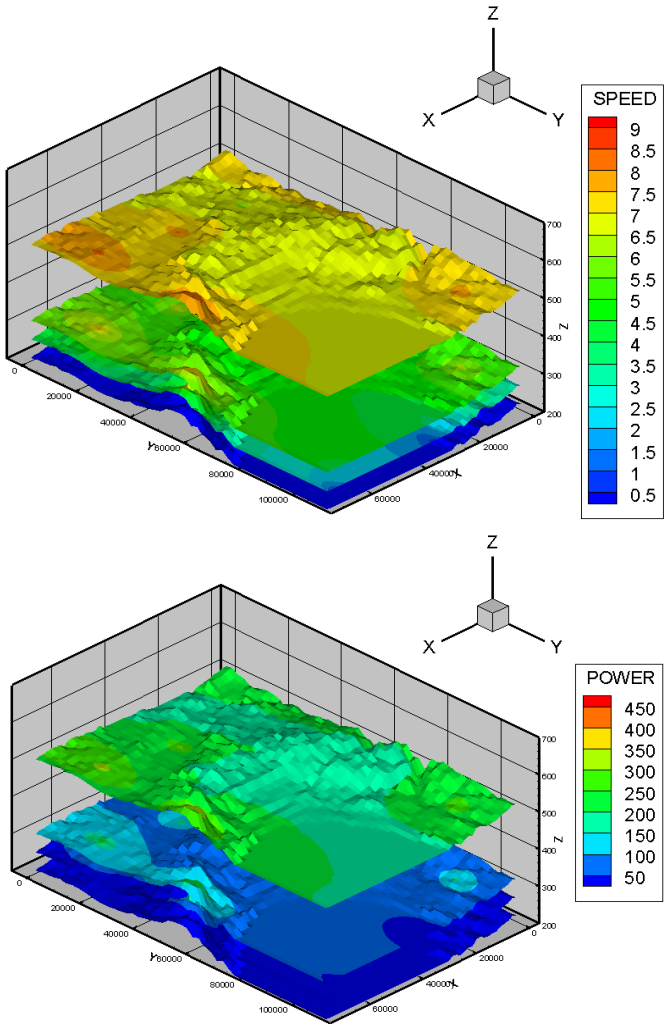
3D Sim & Visualization (Siting)

- **Team:** Constantin Apostoaia, Chenn Zhou, Xiuling Wang, Dave Kozel

- **Research projects:**
  - Constructing 3-D wind field for rural and urban wind farms.
  - Computational Fluid Dynamics simulation of wind turbines.
  - Virtual reality visualization.



Wind field of northwest Indiana



Wind velocity and power density maps in North Western Indiana

Education and Training

Selection and siting of Bergey HAWT in Design Course

Design of rooftop VAWT

Wind Turbine Certificate Program

Group of courses from among set including “Intro to Wind Energy,” “Benefit-Cost Analysis,” “WT Dynamics and Control,” etc.

VAWTs for Urban Wind Farms

Installing VAWTs at Calumet and West Lafayette campuses to provide test beds for student projects.

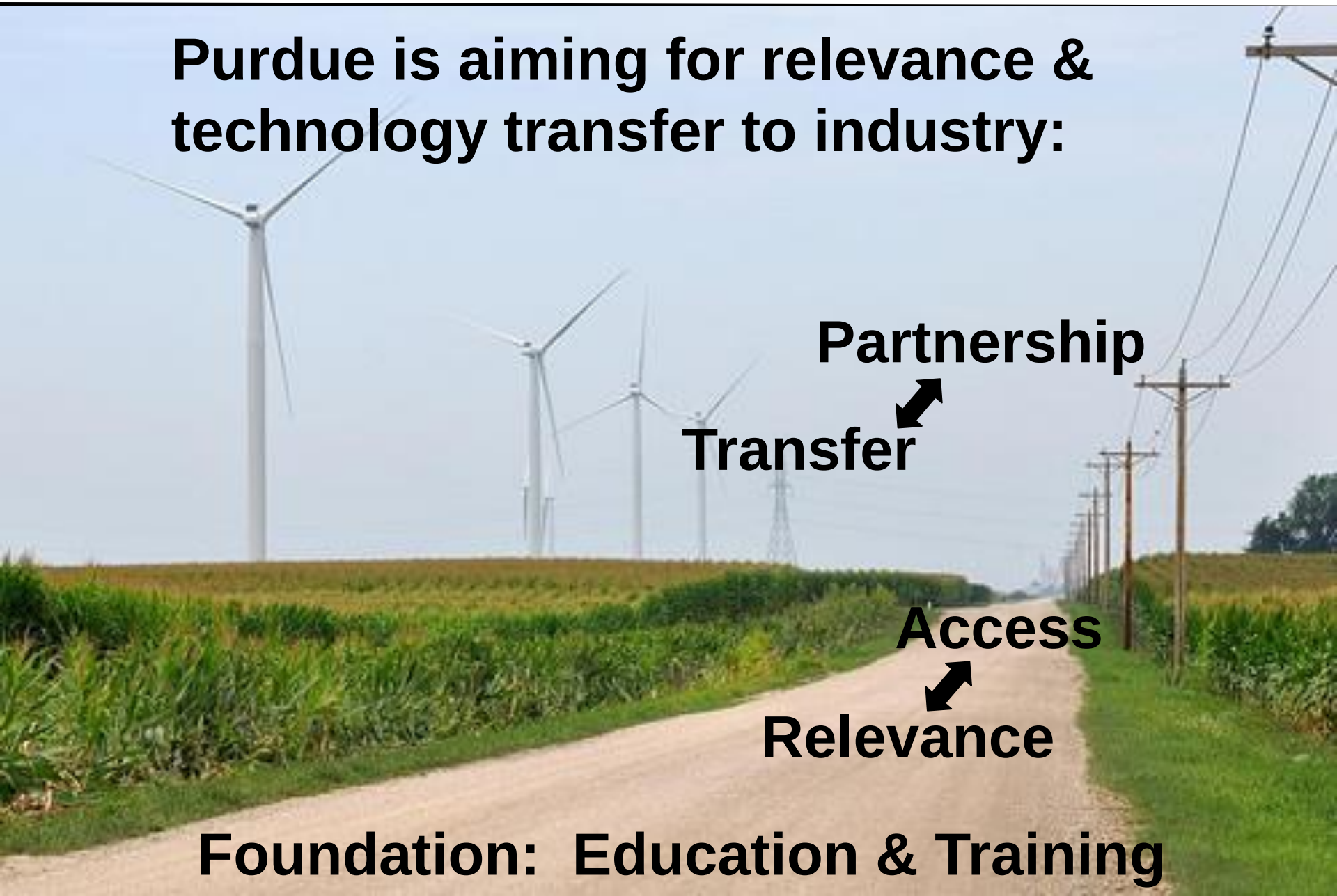
Testbeds for Education and Learning

Setting up portable HAWT for use by Purdue-IUB students, and working with Taylor University to study new HAWTs.

Internships

NREL & Sandia internships.

Conclusions



Purdue is aiming for relevance & technology transfer to industry:

Partnership

Transfer

Access

Relevance

Foundation: Education & Training

Purdue University

Integrating Research into Today's Wind Industry

WIndiana 2010
Indianapolis, IN

Energy Center at Discovery Park
July 22, 2010

PURDUE UNIVERSITY

WIndiana 2010